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Harfoushian

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(54) **FORMATION FRACTURING AND SAMPLING METHODS**

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(51) **Int. Cl.**

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E21B 49/02	(2006.01)
E21B 43/267	(2006.01)
E21B 49/08	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 43/267*** (2013.01); ***E21B 49/082*** (2013.01)

(58) **Field of Classification Search**

CPC E21B 43/162; E21B 43/26; E21B 49/02; E21B 49/08; E21B 49/081; E21B 49/082; E21B 49/10

USPC 166/264, 280.1, 308.1, 305.1, 177.5, 267

See application file for complete search history.

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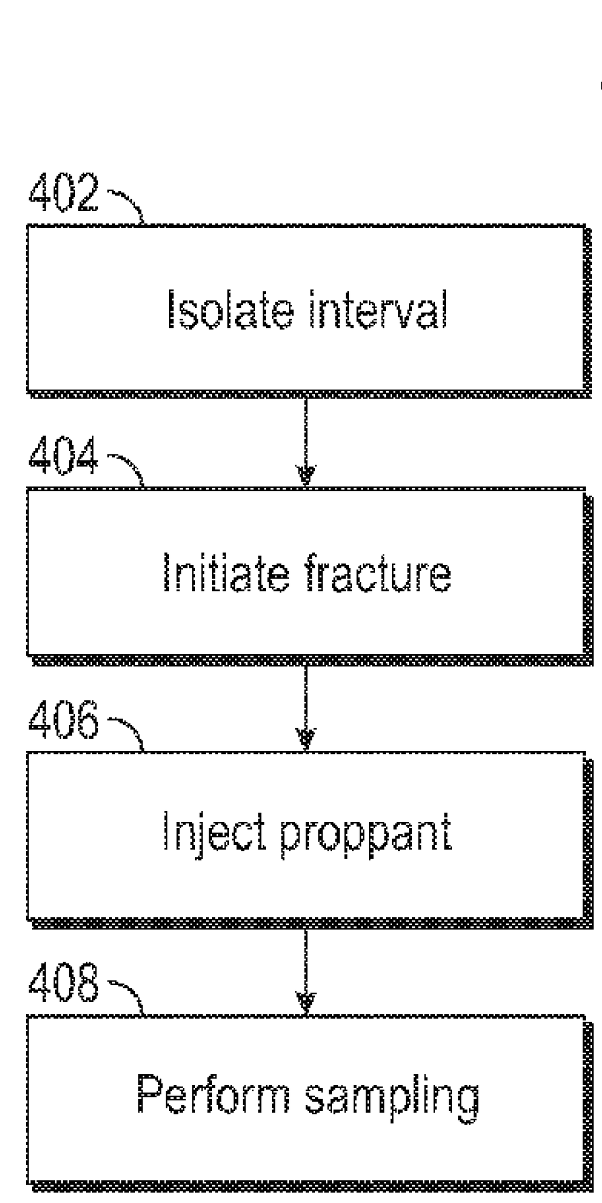
(57) **ABSTRACT**

The present disclosure relates to a method of fracturing and sampling an isolated interval within a wellbore. The method includes deploying a plurality of packers to isolate the interval and initiating a fracture at the isolated interval. The method further includes directing a motive fluid into a proppant injection chamber to direct a proppant stored within the proppant injection chamber into the isolated interval. Sampling also may be performed at the isolated interval.

6 Claims, 4 Drawing Sheets



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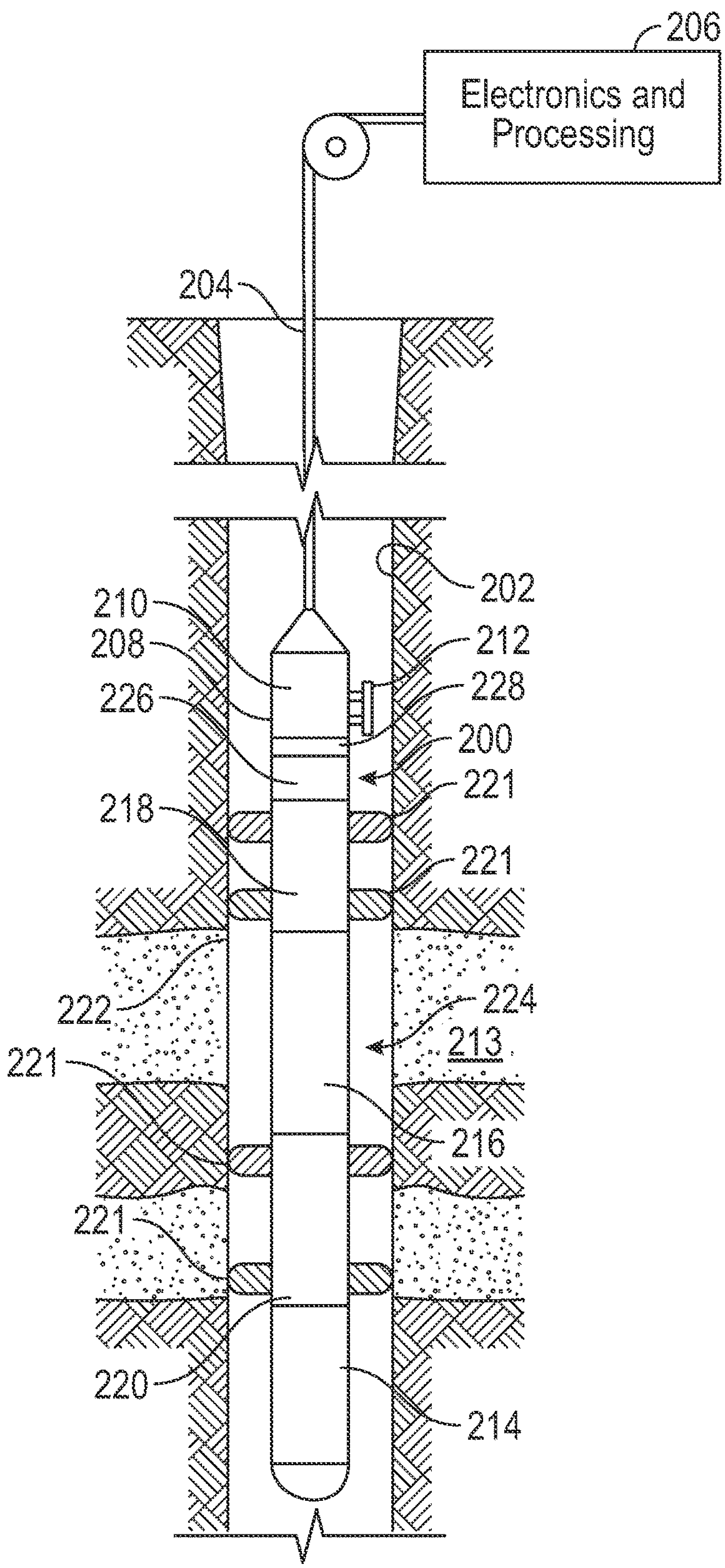
206
Electronics and Processing
204
202
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212
228
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221
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221
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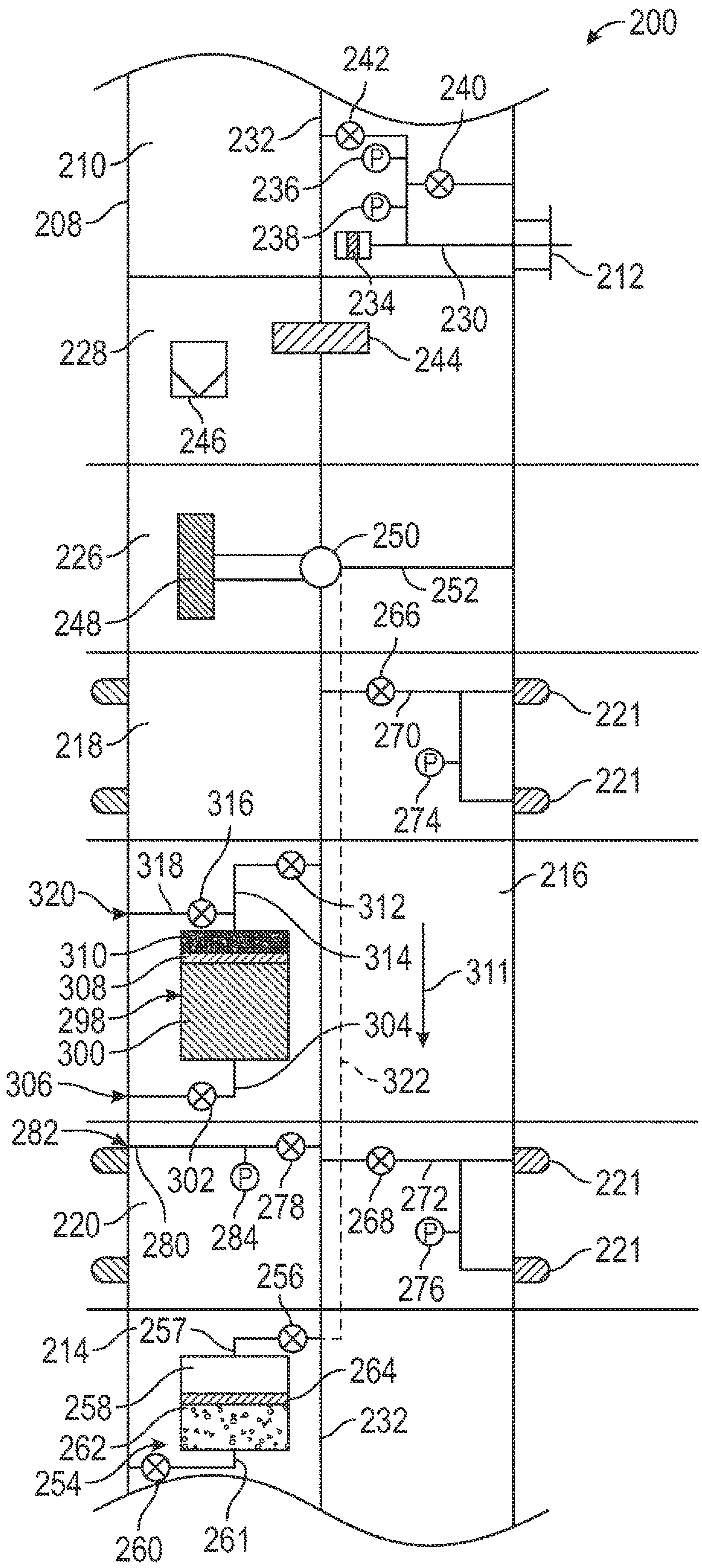
224
213
221
216
221
220
214

FIG. 1


200
242
240
232
210
236
208
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212
234
230
228
244
246
226
250
252
248
266
221
218
270
221
274
316
318
312
216
320
310
314
311
308
298
304
300
322
306
282
302
278
221
272
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284
268
276
221
256
257
214
264
258
232
262
254
260
261

FIG. 2

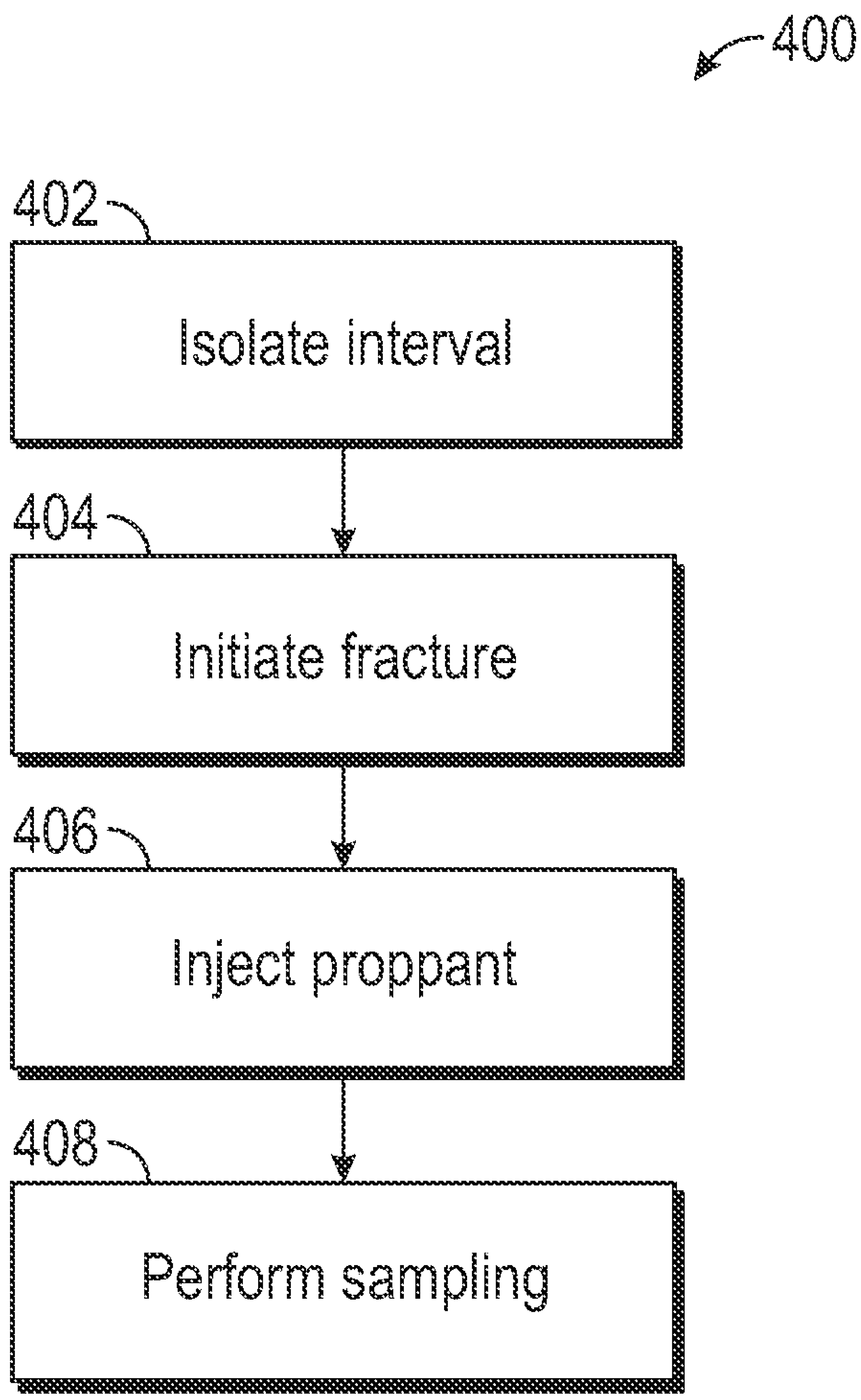
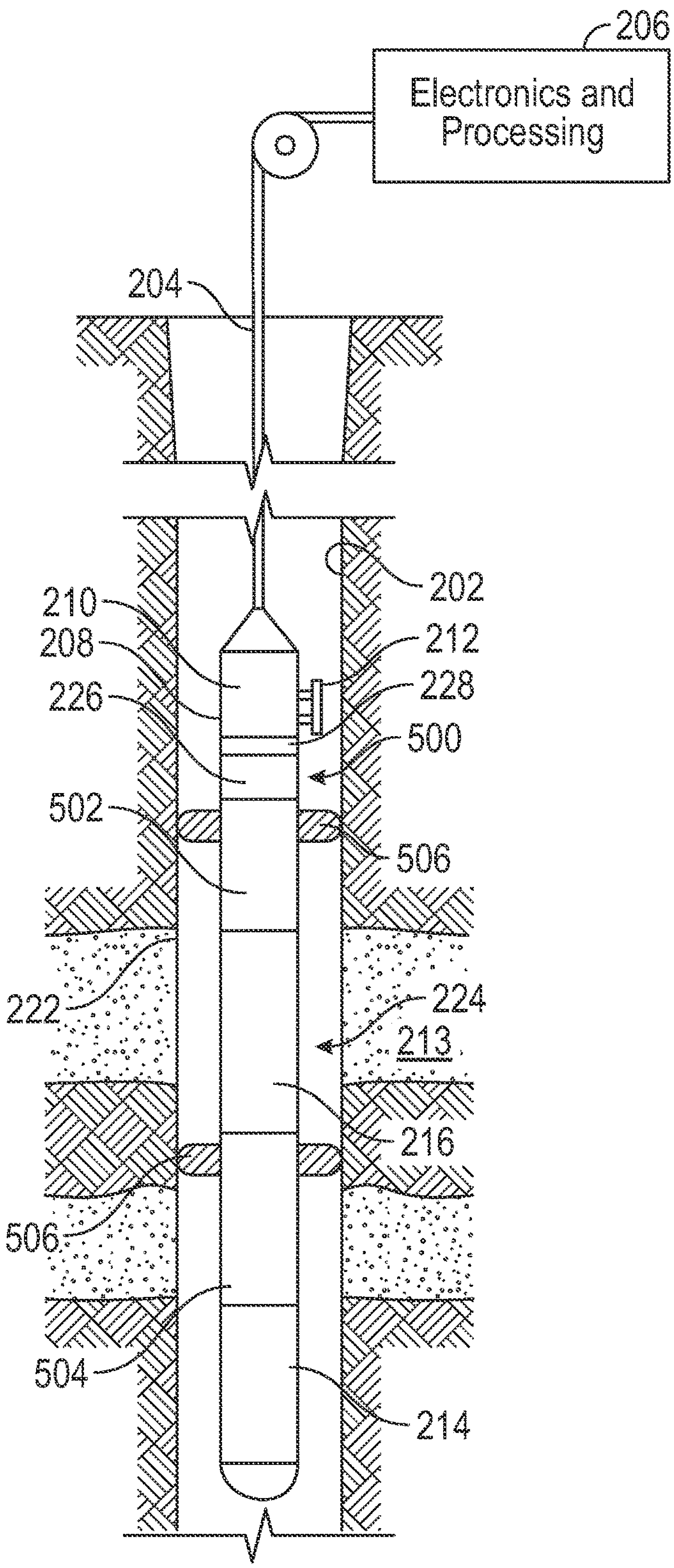

400
402
Isolate interval
404
Initiate fracture
406
Inject proppant
408
Perform sampling

FIG. 3


206
Electronics and Processing
204
202
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212
228
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500
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506
222
224
213
216
506
504
214

FIG. 4

FORMATION FRACTURING AND SAMPLING METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional Patent Application Ser. No. 61/917,494, filed Dec. 18, 2013, which is herein incorporated by reference.

BACKGROUND OF THE DISCLOSURE

Wellbores (also known as boreholes) are drilled to penetrate subterranean formations for hydrocarbon prospecting and production. During drilling operations, evaluations may be performed of the subterranean formation for various purposes, such as to locate hydrocarbon-producing formations and manage the production of hydrocarbons from these formations. To conduct formation evaluations, the drill string may include one or more drilling tools that test and/or sample the surrounding formation, or the drill string may be removed from the wellbore, and a wireline tool may be deployed into the wellbore to test and/or sample the formation. These drilling tools and wireline tools, as well as other wellbore tools conveyed on coiled tubing, drill pipe, casing or other conveyers, are also referred to herein as "downhole tools."

Formation evaluation may involve drawing fluid from the formation into a downhole tool for testing and/or sampling. Various devices, such as probes and/or packers, may be extended from the downhole tool to isolate a region of the wellbore wall, and thereby establish fluid communication with the subterranean formation surrounding the wellbore. To promote fluid communication for low permeability formations, the formation may be fractured prior to sampling.

SUMMARY

The present disclosure relates to a method that includes deploying packers to isolate an interval within a wellbore and initiating a fracture at the isolated interval. The method further includes directing a motive fluid into a proppant injection chamber to direct a proppant stored within the proppant injection chamber into the isolated interval.

The present disclosure also relates to a method that includes conveying a downhole tool within a wellbore, where the downhole tool has an injection module disposed between a first packer module and a second packer module. The method also includes deploying a first packer of the first packer module and a second packer of the second packer module to isolate an interval within the wellbore. The method further includes initiating a fracture at the isolated interval by directing a fracturing fluid into the isolated interval through a port in the second packer module. Moreover, the method includes injecting a proppant into the isolated interval by directing a motive fluid into a proppant injection chamber of the injection module to displace a piston and move the proppant into the isolated interval. The method also includes performing sampling of the isolated interval by directing formation fluid from the isolated interval into the downhole tool through the port in the second packer module.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1** is a schematic view of an embodiment of a wellsite system that may employ fracturing and sampling methods, according to aspects of the present disclosure;

FIG. **2** is a schematic representation of a portion of the downhole tool of FIG. **1**, according to aspects of the present disclosure;

FIG. **3** is a flowchart depicting an embodiment of a method for fracturing and sampling, according to aspects of the present disclosure; and

FIG. **4** is a schematic view of another embodiment of a wellsite system that may employ fracturing and sampling methods, according to aspects of the present disclosure.

DETAILED DESCRIPTION

It is to be understood that the present disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting.

The present disclosure relates to methods for fracturing and sampling formations. According to certain embodiments, an interval of a wellbore may be isolated using a pair of dual or single packer modules. An injection module, disposed on the tool string between the pair of packer modules, may be employed in conjunction with the packer modules to initiate a fracture at the isolated interval. The injection module also may be employed to inject proppant into the fracture. In certain embodiments, the proppant may be stored in a chamber of the injection module. The chamber includes a piston that hydraulically isolates the proppant from a motive fluid, such as mud, or other wellbore fluid, within the chamber. To inject the proppant, the pump may be operated to direct the motive fluid into the chamber and move the piston to direct the proppant into the wellbore. The injection module may further be employed to sample the fractured formation.

FIG. **1** depicts an example of a wellsite system that may employ the fracturing and sampling techniques described herein. A downhole tool **200** is suspended in a wellbore **202** from the lower end of a multi-conductor cable **204** that is spooled on a winch at the surface. The cable **204** is communicatively coupled to an electronics and processing system **206**. The downhole tool **200** includes an elongated body **208** that houses modules **210**, **214**, **216**, **218**, **220**, **226**, and **228** that provide various functionalities including fluid sampling, fluid testing, wellbore isolation, and operational control, among others. The modules may represent independent sections of the downhole tool **200** that can be mechanically coupled together, for example, by pin and box connections or other suitable couplings, to provide electrical communication and fluid communication between the modules. As shown in FIG. **1**, the downhole tool **200** is conveyed on a wireline (e.g., using the multi-conductor cable **204**); however, in other embodiments the downhole tool may be conveyed on a drill string, coiled tubing, wired drill pipe, or other suitable types of conveyance.

As shown in FIG. **1**, the module **210** is a fluid communication module **210** that has a selectively extendable probe **212** that can engage the wall **222** of the wellbore to draw fluid samples from the formation **213**. The probe **212** may include a single inlet or multiple inlets designed for guarded or focused sampling. The formation fluid may be expelled to the wellbore through a port in the body **208** or the formation fluid may be sent to a fluid sampling module **214**. The fluid sampling module **214** may include one or more sample chambers that store the formation fluid.

Formation fluid also may be directed into the downhole tool **200** using the injection module **216**. The injection module **216** is disposed on the downhole tool **200** between a pair of packer modules **218** and **220**. The packer modules **218** and **220** each include a pair of packers that can be expanded to engage the wall **222** of the wellbore **202** and isolate an interval **224** of the wellbore **202**. The isolated interval **224** extends within the wellbore **202** between the packer modules **218** and **220**, and the injection module **216** is disposed within the isolated interval **224**. As described further below with respect to FIG. **3**, the injection module **216** may be employed in conjunction with the packer modules **218** and **220** to fracture the formation **213** at the isolated interval **224** and sample formation fluid.

The downhole tool **200** also includes a pump out module **226** that can be employed to direct fluids through the downhole tool **200**, as well as a fluid analysis module **228** that can be employed to determine properties of the formation fluid. Further, in other embodiments, additional modules may be included in the downhole tool **200** to provide further functionality, such as resistivity measurements, communications, coring, and/or imaging, among others. In the illustrated example, the electronics and processing system **206** and a downhole control system are configured to control operation of the modules.

FIG. **2** is a schematic diagram of a portion of the downhole tool **200** depicting internal fluid flow through the tool. The fluid communication module **210** includes the probe **212** for directing formation fluid into the downhole tool **200**. The fluid communication module **210** includes a probe flowline **230** that directs the fluid to a primary flowline **232** that extends through the downhole tool **200**. The fluid communication module **210** also includes a pump **234** and pressure gauges **236** and **238** that may be employed to conduct formation pressure tests. An equalization valve **240** may be opened to expose the flowline **230** to the pressure in the wellbore, which in turn may equalize the pressure within the downhole tool **200**. Further, an isolation valve **242** may be closed to isolate the formation fluid within the flowline **230**, and may be opened to direct the formation fluid from the probe flowline **230** to the primary flowline **232**.

The primary flowline **232** directs the formation fluid through the downhole tool to the fluid analysis module **228** that includes a fluid analyzer **244**, which can be employed to provide in situ downhole fluid measurements. For example, the fluid analyzer **244** may include an optical spectrometer and/or a gas analyzer designed to measure properties such as, optical density, fluid density, fluid viscosity, fluid fluorescence, fluid composition, oil based mud (OBM), and the fluid gas oil ratio (GOR), among others. One or more additional measurement devices, such as temperature sensors, pressure sensors, resistivity sensors, chemical sensors (e.g., for measuring pH or H_2S levels), and gas chromatographs, may also be included within the fluid analyzer **244**. In certain embodiments, the fluid analysis module **228** may include a controller **246**, such as a microprocessor or control circuitry, designed to calculate certain fluid properties based on the sensor measurements. Further, in certain embodiments, the controller **246** may govern the fracturing and sampling operations. Moreover, in other embodiments, the controller **246** may be disposed within another module of the downhole tool **200**.

The downhole tool **200** also includes the pump out module **226**, which includes a pump **248** designed to provide motive force to direct the fluid through the downhole tool **200**. According to certain embodiments, the pump **248** may be a hydraulic displacement unit that receives fluid into alternating pump chambers. A valve block **250** may direct the fluid into and out of the alternating pump chambers. The valve block **250** also may direct the fluid exiting the pump **248** through the primary flowline **232** or may divert the fluid to the wellbore through an exit flowline **252**.

The downhole tool **200** also includes the sample module **214** designed to store a sample of the formation fluid within a sample chamber **254**. As shown in FIG. **2**, a single sample chamber **254** is included within the sample module **214**. However, in other embodiments, multiple sample chambers may be included within the sample module **214** to provide for storage of multiple formation fluid samples. Further, in other embodiments, multiple sample modules **214** may be included within the downhole tool. Moreover, other types of sample chambers, such as single phase sample bottles, among others, may be employed in the sample module **214**.

The sample chamber **254** includes a floating piston **264** that divides the sample chamber into two volumes **258** and **262**. As the formation fluid flows through the primary flowline **232**, a valve **256** may be actuated to divert the formation fluid through a sample flowline **257** and into the volume **258**. In certain embodiments, the pump **248** may provide the motive force to direct the fluid through the primary flowline **232** and into the sample chamber **254**. The formation fluid may be stored within the volume **258** and, in certain embodiments, may be brought to the surface for further analysis. The sample module **214** also may include a valve **260** that can be opened to expose the volume **262** of the sample chamber **254** to the annular pressure. In certain embodiments, the valve **260** may be opened to allow buffer fluid to exit the volume **262** to the wellbore, which may provide backpressure during filling of the volume **258** that receives formation fluid.

Formation fluid also may be drawn into the downhole tool **200** using the injection module **216** and the dual packer modules **218** and **220**. Each dual packer module **218** and **220** includes a respective valve **266** or **268** that can be actuated to divert fluid from the primary flowline **232** into the packers **221**. For example, mud from the wellbore, or other suitable fluid, may be directed through the primary flowline **232** and diverted to inflation lines **270** and **272** through the valves **266** and **268** to inflate the packers **221**. Pressure gauges **274** and **276** may be disposed in the respective inflation lines **270** and **272** to monitor the pressure and/or to ensure a sufficient seal between the packers **221** and the wellbore wall.

Once the packers **221** have been inflated to seal the interval **224** (FIG. **1**), formation fluid may be drawn into the downhole tool **200** from the interval **224**. For example, the packer module **220** includes an interval valve **278** that may be actuated to direct fluid from the wellbore into a flowline **280** through a port **282** in the body **208** of the downhole tool **200**. As shown in FIG. **2**, the port **282** is disposed on the packer module **220** between the packers **221** and the injection module **216**. However, in other embodiments, the port **282** may be disposed in the injection module **216** or in the packer module **218**, for example between the packers **221** and the injection module **216**. The pump **248** may be operated to draw fluid through the flowline **280**, to the primary flowline **232** where the fluid may be directed to the volume **258** through the sample flowline **257**. A pressure gauge **284** also may be disposed in the flowline **280** for pressure testing, as discussed further below with respect to FIG. **3**.

To facilitate sampling from the interval **224** (FIG. **1**), the injection module **216** may be employed to promote flow of fluid within the formation by maintaining or re-opening a fracture. The injection module **216** is disposed between the two packer modules **218** and **220** to allow fracturing and sampling from the interval **224** without moving the downhole tool **200** within the wellbore. For example, the packer modules **218** and **220** may be employed to isolate the interval **224**. Then, a fracture may be initiated at the interval, for example, using the packer module **220**, as discussed further below with respect to FIG. **3**. Proppant may then be injected into the interval **224** by the injection module **216** to maintain and/or open the fracture. A formation sample may then be obtained from the interval **224**.

The injection module **216** includes a proppant injection chamber **298** that stores proppant within a volume **300**. A flowline **304** is fluidly coupled to the volume **300** and a valve **302** may be actuated to allow proppant to flow into and out of the volume **300** through a port **306** in the body **208** of the downhole tool **200**. The chamber **298** also includes a floating piston **308** that divides the chamber **298** into the volume **300** and another volume **310**. The volume **310** may receive a motive fluid, such as mud or wellbore fluid, that moves the floating piston **308** in the direction of the arrow **311** to inject the proppant into the wellbore. In certain embodiments, the pump **248** may be employed to move the motive fluid through the primary flowline **232** and into the motive fluid line **314** to the volume **310**. Although a single proppant injection chamber **298** is shown in FIG. **3**, in other embodiments, multiple proppant injection chambers may be included within the injection module **216**. Moreover, in certain embodiments, multiple injection modules **216** may be included in the downhole tool between the packer modules.

According to certain embodiments, the volume **300** may be filled with proppant while the downhole tool **200** is positioned at the surface. For example, the valve **302** may be opened and proppant may be directed into the volume **300** through the port **306** and the flowline **304**. As the volume **300** is filled, the piston **310** may move upward (e.g., in the direction opposite to arrow **311**) and motive fluid present within the volume **310** may be directed through the motive fluid line **314**. The valve **312** within the motive fluid line **314** may be closed during the filling process, while a valve **316** disposed in a drain line **318** may be opened, allowing the motive fluid expelled from the volume **310** to exit the downhole tool **200** through a port **320**. After the volume **300** has been filled with proppant, the valves **302** and **316** may be closed to retain the proppant within the volume **300** while the downhole tool **200** is conveyed within the wellbore. Further, in certain embodiments, the valve **302** may remain open, while the valve **316** may be closed to retain the proppant within the volume **300**.

FIG. **3** is a flowchart depicting an embodiment of a method **400** that may be employed to fracture and sample an isolated interval. According to certain embodiments, the method **400** may be executed, in whole or in part, by the controller **246** (FIG. **2**). For example, the controller **246** may execute code stored within circuitry of the controller **246**, or within a separate memory or other tangible readable medium, to perform the method **400**. Further, in certain embodiments, the controller **246** may operate in conjunction with a surface controller, such as the processing system **206** (FIG. **1**), that may perform one or more operations of the method **400**.

The method **400** may begin by isolating (block **402**) an interval within a wellbore. For example, the downhole tool **200** may be conveyed within a wellbore **202** to a desired location, as shown in FIG. **1**. The packers **221** may then be inflated to isolate an interval **224** that extends within the wellbore **202** between the packers **221**. For example, as shown in FIG. **2**, mud or other fluid may be directed into the packers **221** through the inflation lines **270** and **272**. Further, in other embodiments, the packers may be expanded rather than inflated, for example, by actuating a mechanical expansion mechanism. According to certain embodiments, the sealing integrity of the packers **221** may then be verified by performing a pressure test. For example, the pump **248** may be operated to draw fluid from the wellbore into the downhole tool through the port **282**. The pump **248** may then be stopped and the pressure response in the wellbore may be measured, for example using the pressure gauge **284**.

After the interval has been isolated, the method may continue by initiating (block **404**) a fracture at the interval. For example, as shown in FIG. **2**, wellbore fluids, such as mud, may be injected into the interval **224** through the port **282** in the packer module **220**. The fluids may cause the pressure in the interval **224** to increase, thereby producing pressure sufficient to fracture the formation. In certain embodiments, the pump **248** may be operated to draw wellbore fluids into the primary flowline **232**, for example through another port in the downhole tool above or below the interval **224**, and the valve **278** may be opened to direct the fluids out of the port **282** and into the interval **224**. For example, in certain embodiments, wellbore fluids may be drawn into the primary flowline **232** through the exit flowline **252**. The pump **248** may then be stopped and, in certain embodiments, the fracture may close.

Proppant may then be injected (block **406**) into the interval to re-open, or maintain, the fracture. For example, as shown in FIG. **2**, the valve **278** for the port **282** in the packer module **220** may be closed. The valve **302** in the injection module **216** may be opened, or maintained in the open state if already open, to allow proppant to enter the wellbore through the port **306**. Further, the valve **316** may be closed, or maintained in the closed state if already closed, to prevent motive fluid from exiting the downhole tool **200** through the port **320**. According to certain embodiments, the valves **302** and **316** may be manual valves, and in these embodiments, the valves **302** and **316** may be set to the open and closed positions, respectively, at the surface prior to conveying the downhole tool **200** into the wellbore **202**. However, in other embodiments, the valves **316** and **302** may be controllable valves, such as motor driven valves or solenoid valves, among others, that may be actuated by the controller **246** or electronics and processing system **206** while the downhole tool **200** is disposed in the wellbore **202**.

To inject the proppant from the chamber **298** into the interval **224**, the valve **312** may be opened, for example by a control signal sent from the electronics and processing system **206** or the controller **246**. The pump **248** also may be operated to direct motive fluid, such as wellbore fluid, into the volume **310**. In particular, the pump **248** may direct the motive fluid through the primary flowline **232** and the motive fluid line **314** into the volume **310** to move the piston **308** in the direction of the arrow **311**. The movement of the piston **308** may direct the proppant from the volume **300** through the flowline **304** and port **306** into the isolated interval **224**. The piston **308** may allow the pump **248** to be used to inject the proppant (e.g., via the motive fluid), while the pump **248** is hydraulically isolated from the proppant. As the proppant enters the interval **224**, the pressure within the interval **224** may increase, reopening and propagating the previously initiated fracture. Further, proppant from the interval **224** may be pushed into the fracture. After the proppant has been injected into the interval **224**, the pump **248** may be stopped and the valve **312** may be closed.

According to certain embodiments, the pressure fall-off within the interval **224** may be measured, for example, using the pressure gauge **284** in the packer module **220**, and used for pressure and permeability estimations. Further, in certain embodiments, the pump **248** may be employed to draw fluid from the interval **224** into the downhole tool **200**. For example, the valve **278** may be opened and fluid from the interval **224** may be drawn into the downhole tool **200** through the port **282** and the flowline **280** in the packer module **220**. The pump **248** may then be stopped and the pressure response in the wellbore may be measured, for example using the pressure gauge **284**. The pressure response may be employed to determine the formation pressure and permeability of the interval **224**.

Sampling may then be performed (block **408**) at the interval **224**. The placement of the injection module **216** between the packer modules **218** and **220** allows sampling to be performed at the same location in the wellbore as fracturing, without moving the downhole tool **200** within the wellbore **202** between the fracturing and sampling processes. As shown in FIG. **2**, fluid may be withdrawn into the downhole tool **200** through the port **282** in the packer module **220**. The fluid may be directed through the valve **278** and flowline **280** to the primary flowline **232**. The pump **248** may draw the fluid through the primary flowline **232** to the fluid analyzer **244** to determine properties of the fluid. Once the fluid exhibits desired properties, such as low contamination (e.g., a contamination level within a desired range), for example, the fluid may be routed to the sample chamber **254** where the fluid may be stored for retrieval to the surface.

As shown in FIG. **2**, the sample chamber **254** is disposed below the packer module **220**, and accordingly, in this embodiment, a secondary flowline **322** may be employed to route the sample fluid from the pump **248** to the sample chamber **254**. However, in other embodiments, the position of the sample module **214** within the downhole tool **200** may vary. For example, the sample module **214** may be positioned above the pump out module **226**. In these embodiments, the primary flowline **232** may be employed to direct the fluid to the sample chamber **254**. Moreover, in certain embodiments, the respective positions of the modules **208**, **214**, **228**, and **226** may vary.

FIG. **4** depicts another embodiment of a downhole tool **500** that may employ the fracturing and sampling methods described herein. The downhole tool **500** is generally similar to the downhole tool **200** discussed above with respect to FIGS. **2** and **3**; however, the downhole tool employs a pair of single packer modules **502** and **504**, rather than dual packer modules. Each single packer module **502** and **504** includes a packer **506** and **508** that can be employed to isolate the interval **224**. The downhole tool **500** may be employed to perform the method **400** described above with respect to FIG. **4**; however, rather than inflating pairs of packers, single packers may be inflated for each module **502** and **504**.

The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A method comprising:

conveying a downhole tool within a wellbore, the downhole tool comprising an injection module disposed between a first packer module and a second packer module;

deploying a first packer of the first packer module and a second packer of the second packer module to isolate an interval within the wellbore;

initiating a fracture at the isolated interval by directing a fracturing fluid into the isolated interval through a port in the second packer module;

injecting a proppant into the isolated interval by directing a motive fluid into a proppant injection chamber of the injection module to displace a piston and move the proppant into the isolated interval; and

performing sampling of the isolated interval by directing formation fluid from the isolated interval into the downhole tool through the port in the second packer module.

2. The method of claim **1**, wherein initiating the fracture, injecting the proppant, and performing the sampling are performed at a same location within the wellbore.

3. The method of claim **1**, wherein injecting the proppant comprises pumping the motive fluid into a first volume of the proppant injection chamber via a pump to displace the piston and decrease a second volume of the proppant injection chamber containing the proppant.

4. The method of claim **3**, wherein initiating the fracture comprises pumping the fracturing fluid to the port in the second packer module via the pump.

5. The method of claim **1**, wherein injecting the proppant comprises opening a motive fluid line valve and closing a valve to the port in the second packer module.

6. The method of claim **1**, wherein performing the sampling comprises analyzing a contamination level of the formation fluid and diverting the formation fluid to a sample chamber in response detecting that the contamination level is within a desired range.

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